

WHAT IS CLAIMED IS:

1. A method for operating a combustion device, the method comprising the steps of:

producing a fuel gas using a liquid fuel comprising hydrocarbon molecules
5 and a first gas stream with an oxygen content less than that of ambient air;
premixing the fuel gas and a second gas to produce a gas mixture at a
location upstream of a combustion zone of a combustion device the second gas
including oxygen; and
combusting the gas mixture in the combustion zone of the combustion
10 device, whereby auto-ignition of the gas mixture upstream of the combustion zone
is substantially suppressed.

2. The method of Claim 1, wherein the gas mixture has an amount of
oxygen sufficient to support combustion of the gas mixture.

3. The method of Claim 1, wherein the gas mixture is a lean mixture with
15 an equivalence ratio less than 1.

4. The method of Claim 1, wherein at least 50 weight percent of the
hydrocarbon molecules of the liquid fuel have at least two carbon atoms.

5. The method of Claim 1, wherein the oxygen content of the first gas
stream is below a limiting oxygen index of the liquid fuel.

20 6. The method of Claim 1, wherein the combustion device includes a fuel
metering system configured for natural gas.

7. The method of Claim 1, wherein the first gas stream is supplied by an air
separator.

8. The method of Claim 7, wherein the air separator produces the first gas stream using adsorption.

9. The method of Claim 7, further comprising the step of supplying an oxygen enriched stream from the air separator to the combustion device.

5 10. The method of Claim 9, wherein the oxygen enriched stream is fed to the combustion device downstream of the combustion zone.

11. The method of Claim 9, wherein the oxygen enriched stream is mixed with the reduced oxygen fuel gas in the premixing step.

10 12. The method of Claim 1, wherein the reduced oxygen gas stream is supplied from an exhaust of a pre-burner.

13. The method of Claim 1, wherein the reduced oxygen gas stream is supplied from an exhaust of the combustion device.

15 14. The method of Claim 1, wherein an equivalence ratio of the gas mixture is less than a minimum equivalence ratio at which methane could be combusted under equivalent operating conditions.

15. The method of Claim 1, wherein the liquid fuel is diesel fuel.

16. The method of Claim 1, wherein the liquid fuel is heating oil.

17. The method of Claim 1, wherein the liquid fuel is butane.

18. The method of Claim 1, wherein the liquid fuel is propane.

20 19. The method of Claim 1, wherein the liquid fuel is pentane.

20. The method of Claim 1, wherein the liquid fuel is gasoline.

21. The method of Claim 1, wherein the liquid fuel is a flammable liquid waste.

22. The method of Claim 1, wherein the combustion device is a gas turbine engine.

23. A method for operating a combustion device configured to combust natural gas in a lean, premixed mode, the method comprising the steps of:

5 vaporizing a higher hydrocarbon liquid fuel using a gas stream having a reduced oxygen content relative to ambient air to produce a reduced oxygen fuel gas;

 premixing the reduced oxygen fuel gas and a second gas to produce a gas mixture at a location upstream of a combustion zone of a combustion device, the
10 gas mixture having an amount of oxygen sufficient to support combustion of the gas mixture, the gas mixture having an equivalence ratio less than one, the combustion device being configured to combust natural gas; and

 combusting the gas mixture in the combustion zone of the combustion device, whereby auto-ignition of the gas mixture upstream of the combustion zone
15 is substantially suppressed.

24. The method of Claim 23, wherein the gas stream is derived from an exhaust gas stream of the combustion device.

25. The method of Claim 23, wherein the gas stream is provided by an air separator unit.

20 26. The method of Claim 23, wherein an oxygen rich gas stream from the air separator unit is input to the combustion device.

27. A combustion system comprising:

a combustion device, the combustor having an inlet for accepting a vaporized fuel, a combustion zone, and a premixing zone upstream of the combustion zone, the combustion device being configured to mix the vaporized
5 fuel with an oxygenated gas stream in the premixing zone to produced a mixture suitable for combustion in the combustion zone; and

a fuel vaporization unit connected to the inlet of the combustion device, the fuel vaporization unit being configured to supply a reduced oxygen vaporized fuel gas stream to the combustion device via the inlet, the fuel vaporization unit
10 including a fuel vaporizer with a first inlet connectable to a liquid fuel source and a second inlet connectable to a reduced oxygen gas stream.

28. The system of Claim 27, wherein the combustion device is configured combust the reduced oxygen vaporized fuel gas at an equivalence ratio less than 1.

29. The system of Claim 27, wherein at least 50 weight percent of the
15 hydrocarbon molecules of the liquid fuel from the liquid fuel source have at least two carbon atoms.

30. The system of Claim 27, wherein the oxygen content of the reduced oxygen gas stream is below a limiting oxygen index of the liquid fuel.

31. The system of Claim 27, wherein the combustion device includes a fuel
20 metering system configured for natural gas.

32. The system of Claim 27, wherein the fuel vaporization unit further comprising an air separation unit configured to produce a reduced oxygen stream at

a first outlet, the first outlet being connected to the second inlet of the fuel vaporizer.

33. The system of Claim 32, wherein the air separator produces the reduced oxygen stream by adsorption.

5 34. The system of Claim 32, wherein the air separation unit is further configured to produce an oxygen enriched stream at a second outlet, the second outlet being connected to the combustion device.

35. The system of Claim 34, wherein the second outlet is connected to supply the oxygen enriched stream to the combustion device downstream of the
10 combustion zone.

36. The system of Claim 34, wherein the second outlet is connected to supply the oxygen enriched stream to the premixing zone of the combustion device.

37. The system of Claim 27, wherein the reduced oxygen gas stream is
15 supplied from an exhaust gas stream output by the combustion device.

38. The system of Claim 27, wherein the combustion device gas is configured to mix the vaporized fuel with the oxygenated gas stream such that the mixture has an equivalence ratio less than a minimum equivalence ratio at which methane could be combusted under equivalent operating conditions.

20 39. The system of Claim 27, wherein the liquid fuel is a liquified gas, the liquified gas being of a composition that would be in a gaseous state at room temperature under atmospheric pressure.

40. The system of Claim 27, wherein the liquid fuel is a fuel selected from the group consisting of diesel fuel, heating oil, liquified butane, liquified propane, liquified pentane, gasoline, and flammable liquid waste.

5 41. The system of Claim 27, wherein the combustion device is a gas turbine engine.

42. The system of Claim 27, wherein the combustion device is a rich-quench-lean combustion device.

43. A method for producing a gaseous fuel stream that is resistant to auto-ignition comprising the step of mixing a vaporized liquid fuel with a reduced oxygen gas stream having an oxygen content less than that of ambient air.

10

44. The method of Claim 43, wherein the reduced oxygen gas stream has an oxygen content below a limiting oxygen index corresponding to the vaporized liquid fuel.

45. The method of Claim 43, wherein the vaporized liquid fuel and the reduced oxygen gas stream are mixed such that the gaseous fuel stream has an energy content approximately equal to that of natural gas.

15

46. The method of Claim 45, wherein the energy content of the gaseous fuel stream is approximately equal to the energy content of natural gas on a volumetric basis.

20 47. The method of Claim 45, wherein the energy content of the gaseous fuel stream is approximately equal to the energy content of natural gas on a mass basis.

48. A method for producing a gaseous fuel stream that is resistant to auto-ignition comprising the step of vaporizing a liquid fuel using a reduced oxygen gas stream having an oxygen content less than that of ambient air.

49. The method of Claim 48, wherein the reduced oxygen gas stream has an oxygen content below a limiting oxygen index corresponding to the liquid fuel.

50. The method of Claim 48, wherein the liquid fuel and the reduced oxygen gas stream are mixed such that the gaseous fuel stream has an energy content approximately equal to that of natural gas.

51. The method of Claim 48, wherein the energy content of the gaseous fuel stream is approximately equal to the energy content of natural gas on a volumetric basis.

52. The method of Claim 48, wherein the energy content of the gaseous fuel stream is approximately equal to the energy content of natural gas on a mass basis.

53. A fuel vaporization unit, comprising:

a fuel vaporizer;

a source of liquidized fuel connected to the fuel vaporizer to provide a flow of liquidized fuel; and

a source of reduced oxygen gas connected to the fuel vaporizer to provide a flow of reduced oxygen gas;

wherein the fuel vaporizer produces a vaporized fuel from the liquidized fuel and the reduced oxygen gas.

54. The fuel vaporization unit of Claim 53, wherein the fuel vaporizer is connected to a combustor for receiving the produced vaporized fuel.

55. The vaporization unit of Claim 54, wherein the combustor is connected to a source of oxygenated gas for receiving a flow of oxygenated gas.

5 56. The fuel vaporization unit of Claim 55, wherein the oxygenated gas and the vaporized fuel are mixed and combusted by the combustor.

57. The fuel vaporization unit of Claim 53, wherein the source of reduced oxygen gas includes an air compressor.

10 58. The fuel vaporization unit of Claim 57, wherein the air compressor receives a flow from an exhaust stream.

59. The fuel vaporization unit of Claim 58, wherein the fuel vaporizer is connected to an engine.

60. The fuel vaporization unit of Claim 59, wherein the engine includes a turbine.

15 61. The fuel vaporization unit of Claim 59, wherein the engine is selected from a group consisting of a compression ignition engine and a spark ignition engine.

62. The fuel vaporization unit of Claim 59, wherein the engine has an exhaust for producing the exhaust stream.

20 63. The fuel vaporization unit of Claim 59, wherein the engine includes a combustor.

64. The fuel vaporization unit of Claim 63, wherein the fuel vaporizer is connected to the combustor of the engine.

65. The fuel vaporization unit of Claim 59, wherein the engine is connected to an output device.

66. The fuel vaporization unit of Claim 65, wherein the output device is selected from a group consisting of a generator, a propeller, and a vessel screw.

5 67. A fuel vaporization unit, comprising:

 a fuel vaporizer;

 a source of liquidized fuel connected to the fuel vaporizer to provide a flow of liquidized fuel; and

 an air separator having a reduced oxygen gas flow output, the reduced oxygen gas flow output being connected to the fuel vaporizer;

 wherein the fuel vaporizer produces a vaporized fuel from the liquidized fuel and the reduced oxygen gas flow.

68. The fuel vaporization unit of Claim 67, wherein the air separator is connected to the fuel vaporizer via a first compressor.

15 69. The fuel vaporization unit of Claim 68, wherein the first compressor compresses the reduced oxygen gas flow.

70. The fuel vaporization unit of Claim 67, wherein the vaporized fuel from the fuel vaporizer is fed to an engine.

20 71. The fuel mixing device of Claim 70, wherein the engine is selected from a group consisting of a compression ignition engine and a spark ignition engine.

72. The fuel vaporization unit of Claim 67, wherein the air separator has an oxygen-rich stream output.

73. The fuel vaporization unit of Claim 72, wherein the vaporized fuel from the fuel vaporizer is fed to a combustor.

74. The fuel vaporization unit of Claim 73, wherein the oxygen-rich stream output of the air separator is fed to the combustor.

5 75. The fuel vaporization unit of Claim 73, wherein the oxygen-rich stream output of the air separator is fed to the combustor via a second compressor.

76. The fuel vaporization unit of Claim 73, wherein the combustor produces a combustion output fed to a turbine.

10 77. The fuel vaporization unit of Claim 76, wherein the turbine drives a compressor.

78. The fuel vaporization unit of Claim 77, wherein the compressor has a compressed gas output, the compressed gas output being fed to the air separator.

79. The fuel vaporization unit of Claim 78, wherein the compressor compresses air.

15 80. The fuel vaporization unit of Claim 75, wherein compressed air is extracted from an intermediate stage of the compressor and is fed to the air separator.

81. A method for producing vaporized fuel, the method comprising:
feeding a reduced oxygen gas stream to a fuel vaporizer;
20 feeding liquid fuel to the fuel vaporizer;
the vaporizer unit vaporizing the liquid fuel; and
the vaporizer unit mixing the reduced oxygen gas stream and the vaporized liquid fuel.

82. The method of Claim 81, wherein the mixed reduced oxygen gas and vaporized fuel is fed to an engine.
83. The method of Claim 81, wherein the mixed reduced oxygen gas and vaporized fuel is fed to a combustor.
- 5 84. The method of Claim 83, wherein the combustor receives an oxygenated gas stream, and wherein the combustor mixes and combusts the oxygenated gas stream with the mixed reduced oxygen gas and vaporized fuel.
85. The method of Claim 81, wherein the reduced oxygen gas stream comprises an exhaust gas.
- 10 86. The method of Claim 85, wherein the exhaust gas is produced by an engine.
87. The method of Claim 86, wherein the engine is selected from a group consisting of a spark ignition engine and a compression ignition engine.
88. The method of Claim 86, wherein the engine includes a combustor.
- 15 89. The method of Claim 88, wherein the combustor produces a combustion output that is fed to an output device.
90. The method of Claim 89, wherein the output device comprises a turbine.
91. The method of Claim 90, wherein the turbine produces the exhaust gas.
- 20 92. The method of Claim 81, further comprising:
compressing the reduced oxygen gas stream.
93. The method of Claim 81, wherein the reduced oxygen gas stream is produced by an air separator.

94. The method of Claim 93, further comprising:
compressing the reduced oxygen gas stream.

95. The method of Claim 93, wherein the mixed reduced oxygen gas and
vaporized fuel is fed to an engine.

5 96. The method of Claim 95, wherein the engine is selected from a group
consisting of a spark ignition engine and a compression ignition engine.

97. The method of Claim 95, wherein the engine includes a combustor.

98. The method of Claim 95, wherein the engine comprises a gas turbine.

99. The method of Claim 95, wherein the air separator produces an oxygen
10 rich stream.

100. The method of Claim 99, further comprising:
compressing the oxygen rich stream.

101. The method of Claim 99, wherein the produced oxygen rich stream is
fed to the engine.

15 102. The method of Claim 101, wherein the engine includes a compressor,
and wherein the compressor produces a compressed gas output.

103. The method of Claim 102, wherein the compressed gas output is fed
to the air separator.

104. The method of Claim 102, wherein the compressed air is extracted
20 from an intermediate stage of the compressor and is fed to the air separator.

105. A method for operating a combustion device, the method comprising
the steps of:

producing a fuel gas using a liquid fuel comprising hydrocarbon molecules and a gas stream with an oxygen content less than that of ambient air; and

combusting the fuel gas in the combustion zone of the combustion device, whereby the heat capacity of the reduced-oxygen stream serves to reduce the flame temperature and thereby reduce NO_x emissions.

106. The method of Claim 105, wherein the combustion device uses a diffusion flame.

107. The method of Claim 105, wherein at least 50 weight percent of the hydrocarbon molecules of the liquid fuel have at least two carbon atoms.

108. The method of Claim 105, wherein the oxygen content of the reduced oxygen gas is below a limiting oxygen index of the liquid fuel.

109. The method of Claim 105, wherein the combustion device includes a fuel metering system configured for natural gas.

110. The method of Claim 105, wherein the reduced oxygen gas stream is supplied by an air separator.

111. The method of Claim 110, wherein the air separator produces the reduced oxygen stream using adsorption.

112. The method of Claim 110, further comprising the step of supplying an oxygen enriched stream from the air separator to the combustion device.

113. The method of Claim 112, wherein the oxygen enriched stream is fed to the combustion device downstream of the combustion zone.

114. The method of Claim 105, wherein the reduced oxygen gas stream is supplied from a pre-burner.